



# **NASA SnowEx 2020**

**Grand Mesa Intensive Observing Period (IOP)**

**Organizing Team: Carrie Vuyovich, HP Marshall, Chris Hiemstra,  
Kelly Elder, Jerry Newlin, Mike Durand, Ludo Brucker**



# SnowEx 2020 – Grand Mesa

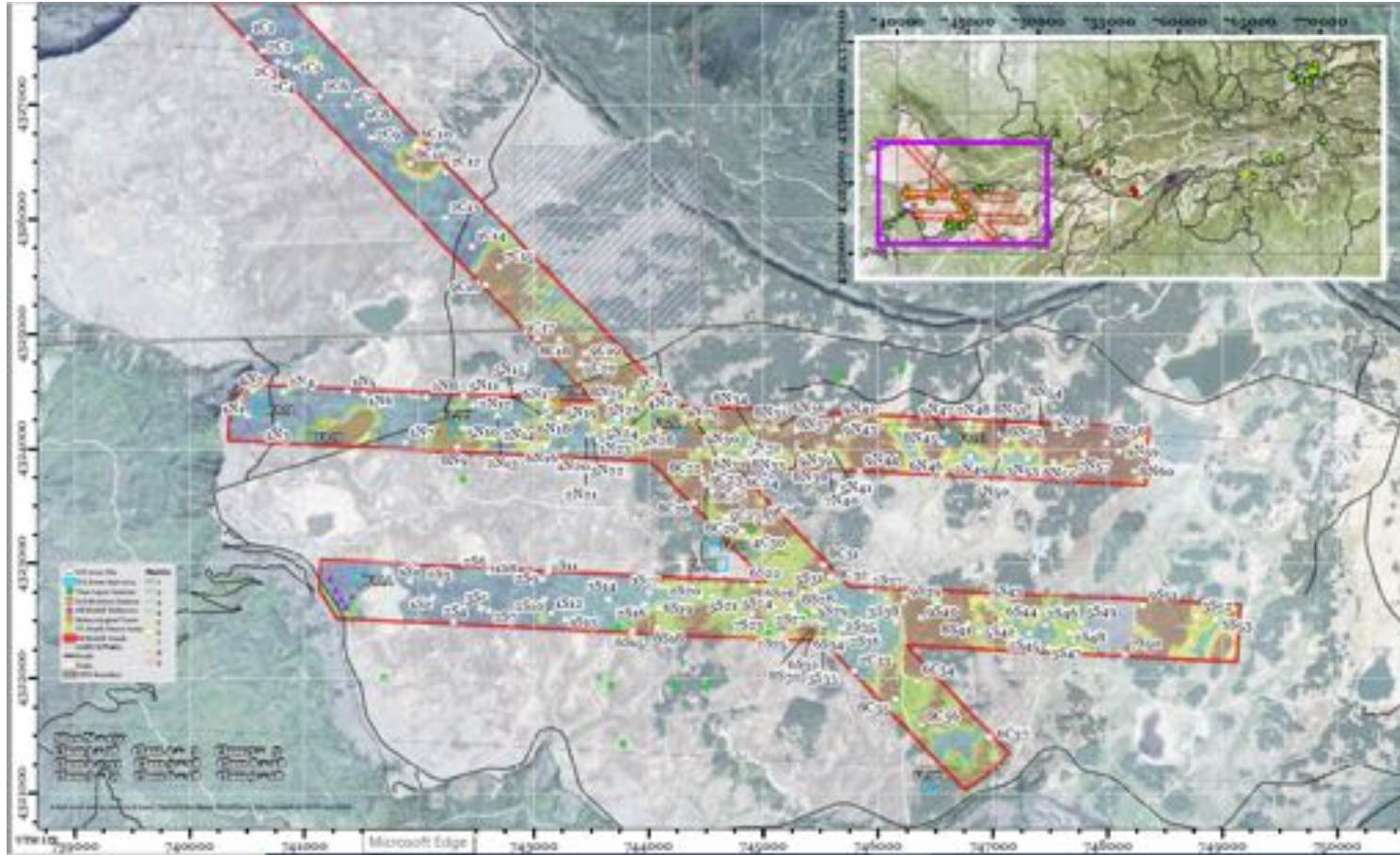
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## Primary Objectives:

1. Collect data needed test and validate SWE retrieval from active and passive microwave sensors
  2. Collect thermal IR data to assess the value of kilometer-scale satellite IR observations (e.g., GOES-16/17) for snow energy balance modeling
- Focus on flat, open shrubland and meadows and transitioning into forests
  - Ground observations of:
    - Snow depth and surface temperature spatial variability
    - Vertical profiles of snow stratigraphy and microstructure

# Grand Mesa Sampling Design



## Planned Ground Observations:

- Snow pits (150)
- Snow Depth Transects

## Planned Ground-based Instruments:

- Terrestrial Laser Scanner (TLS)
- Magnaprobe
- Radiometer
- Ground penetrating radar
- Snow micropenetrometer (SMP)
- IceCube/IRIS
- Snow casting/Micro-CT
- Snow surface temperature



# Grand Mesa Ground Participants

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First shift participants



Second shift participants

# Grand Mesa Participants and Field Roles

Name	Primary Role	Week 1	Week 2	Week 3
Kelly Elder	Pit	X	X	
Chris Hiemstra	Depth/Pit	X	X	X
Glen Liston	Depth/Pit	X	X	
Carl Green	Pit	X	X	
Jewell Lund	Pit/ASD	X		X
Hans Lievens	Pit	X	X	
Carrie Vuyovich	Pit	X	X	X
Jeremy Johnson	Depth/Pit	X	X	
Cassie Lumbrazo	Pit		X	
Jessica Lundquist	Pit			X
Steve Pestana	Depth		X	X
Paul Houser	Depth	X	X	
Juha Lemmetyinen	SSA	X	X	
Celine Vargel	SSA	X	X	
Kehan Yang	SSA		X	
Kate Hale	SSA			X
Lauren Farnsworth	Snow casting		X	X
Megan Mason	SMP	X	X	X
Ioanna Merkouriadi	SMP	X	X	
HP Marshall	FMCW Radar	X	X	X
Ryan Webb	GPR	X	X	
Randall Bonnell	GPR	X	X	

Name	Primary Role	Week 1	Week 2	Week 3
Tate Meehan	GPR/SMP	X	X	
Mike Durand	Radiometer		X	X
Art Gelvin	TLS	X	X	
Manny Salgado	TLS	X	X	
Jake Graham	TLS	X		
Ahmad Hojatimalekshah	TLS	X	X	
Josh Enterkine	TLS	X	X	
Alex Stott	SUS-V Operator	X	X	
Bruce Elder	Pit/Strength	X	X	
Jerry Newlin	Logistics	X	X	X
Mark Thomas	Logistics	X	X	
Joann Collins	Logistics	X	X	
Brian Haught	Logistics	X	X	X
Alej Guzman	Logistics	X	X	
Trey Stafford	NSIDC	X		
Jill Foster	NSIDC	X		
Marin Klinger	NSIDC		X	
Stephanie Miller Wong	NSIDC		X	
Suzanne Craig	NSIDC			X
Steve Tanner	NSIDC			X
Jessica Merzdorf	Media			X
Ryan Fitzgibbons	Media			X



# Ground Campaign Summary

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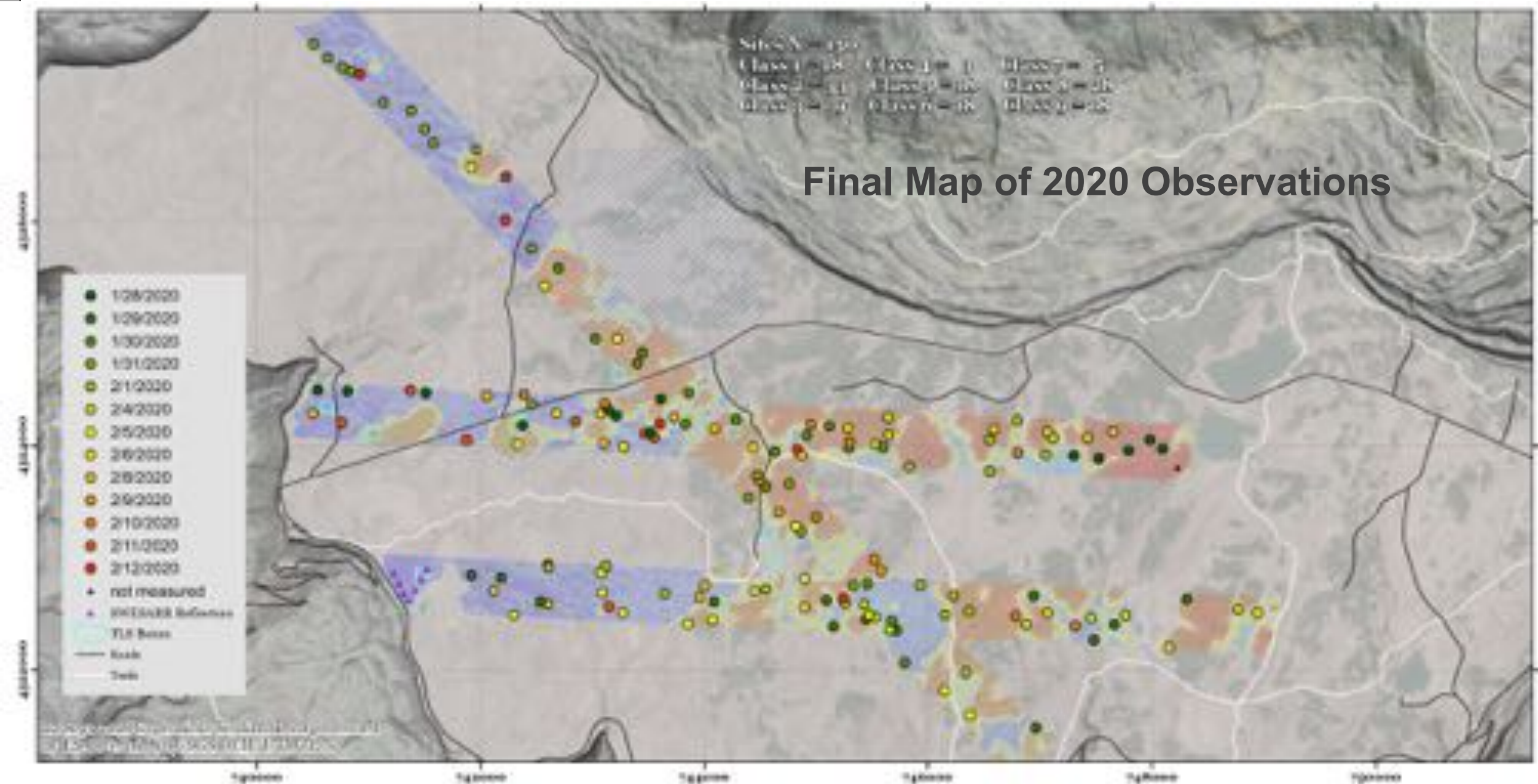
- 153 Snow Pits
- Over 30,000 snow depth measurements
- SSA profiles at 99 pits
- 976 SMP profiles at 48 pits
- 73 snow casts at 12 pits
- PM radiometer measurements at 20 pits + grid
- IR radiometers & temperature profiles installed at 2 locations for 2-week period
- 4 radars covered over 500 km
- ASD measurements during both Quantum hyperspectral flights
- 9 TLS sites scanned
- 8 storm boards & 12 snow stakes installed and measured three times (2, 8, 13 Feb)
- SUS-V mobility measurements (coordinated activity)
- Drone flights (Thermal IR, SfM) (coordinated activity)



Teams getting ready in the morning (photo by Jewell Lund)



# Final Map of 2020 Observations



# Snow pits



Snow pit with Celine Vargel, Jewell Lund and Trey Stafford (Photo by Megan Mason)



Megan Mason, Chris Hiemstra and Kate Hale working in the snow pit (Photo by HP Marshall)



# Snow depth



Paul Houser collecting snow depth (Photo by Ioanna Merkouriadi)

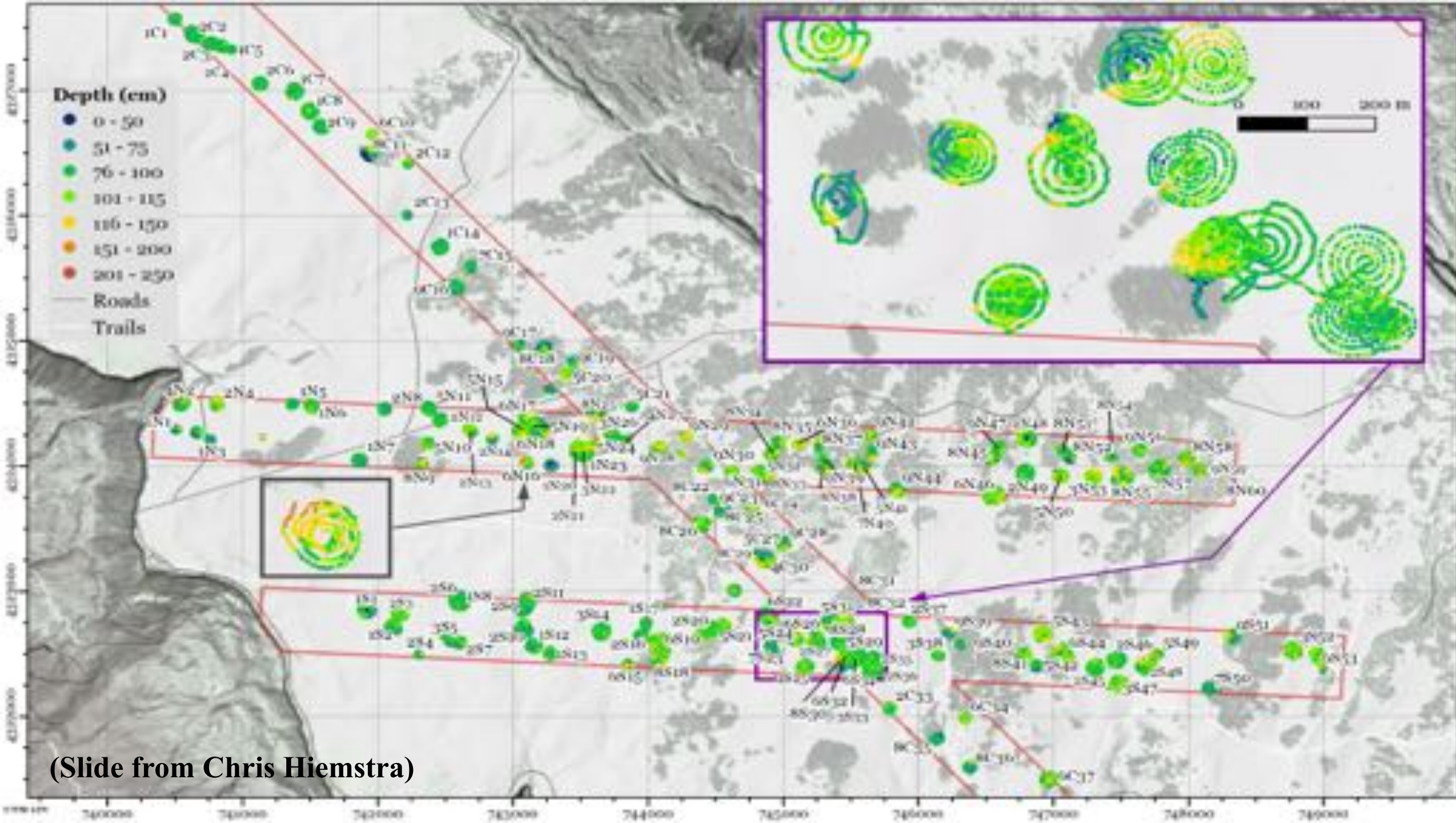


Cassie Lumbrazo collecting snow depth (photo by Celine Vargel)

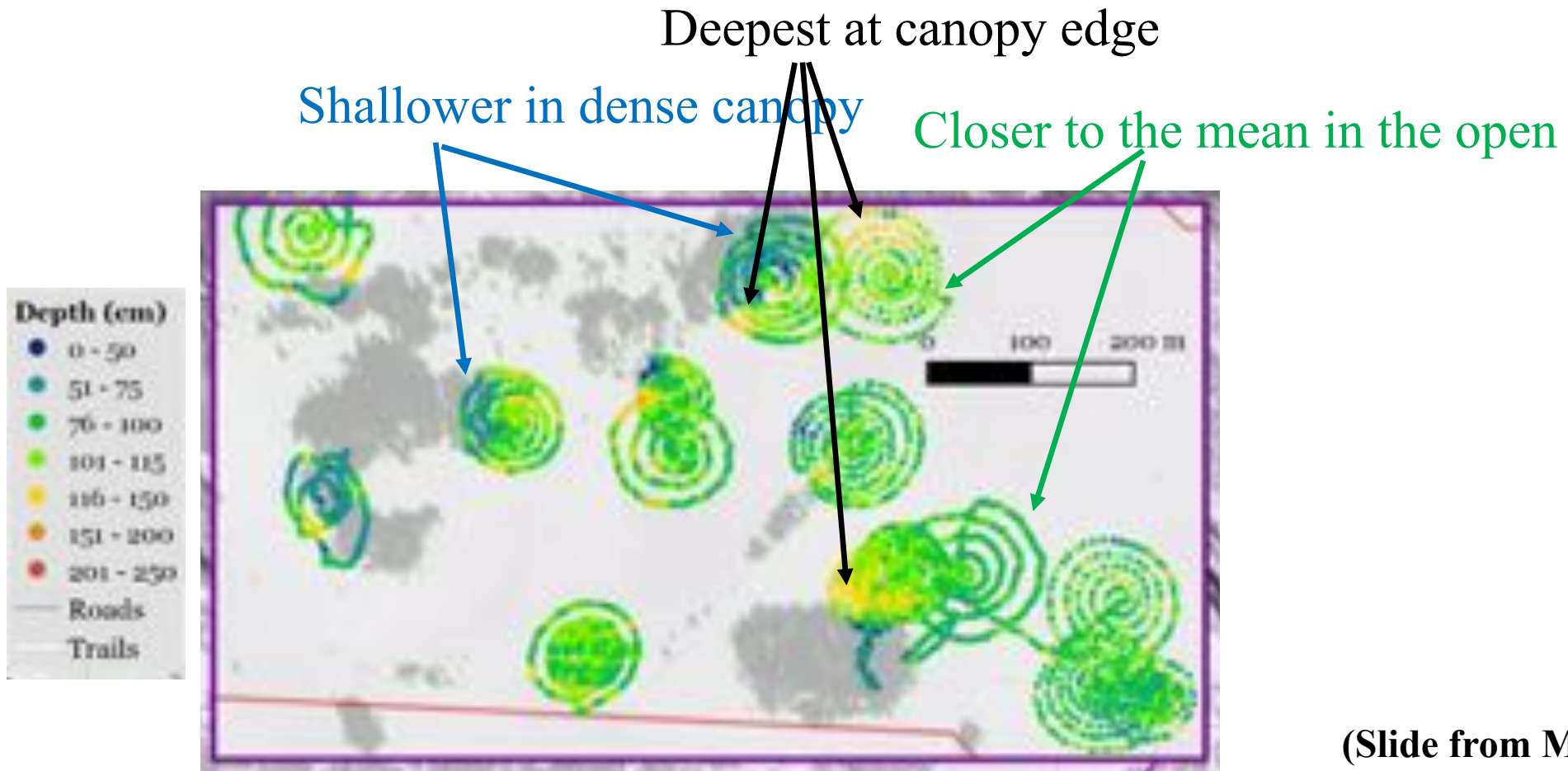


Ioanna Merkouriadi showing her depth transect skills (photo by Chris Hiemstra)





# Snow depth distribution



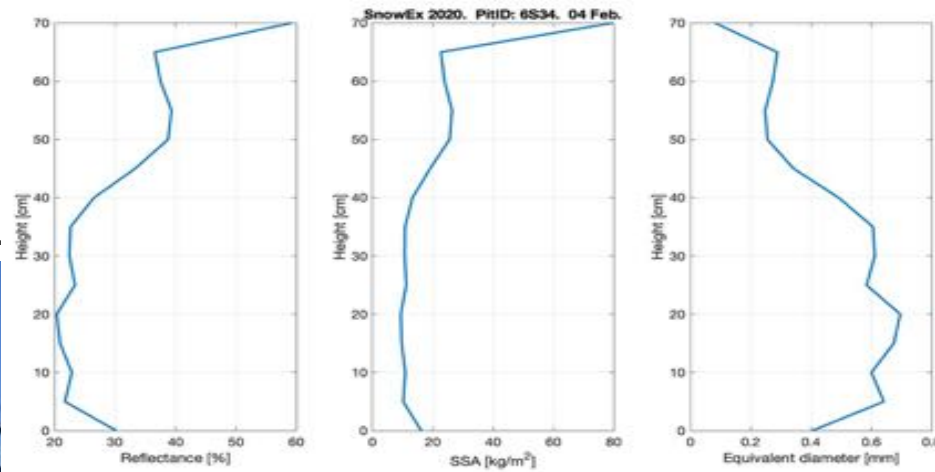
(Slide from Megan Mason)



# SSA



Kehan Yang collecting SSA with IceCube (field camera)



Juha Lemmetyinen and Celine Vargel side-by-side SSA comparison with IceCube and IRIS (Photo by Carrie Vuyovich)

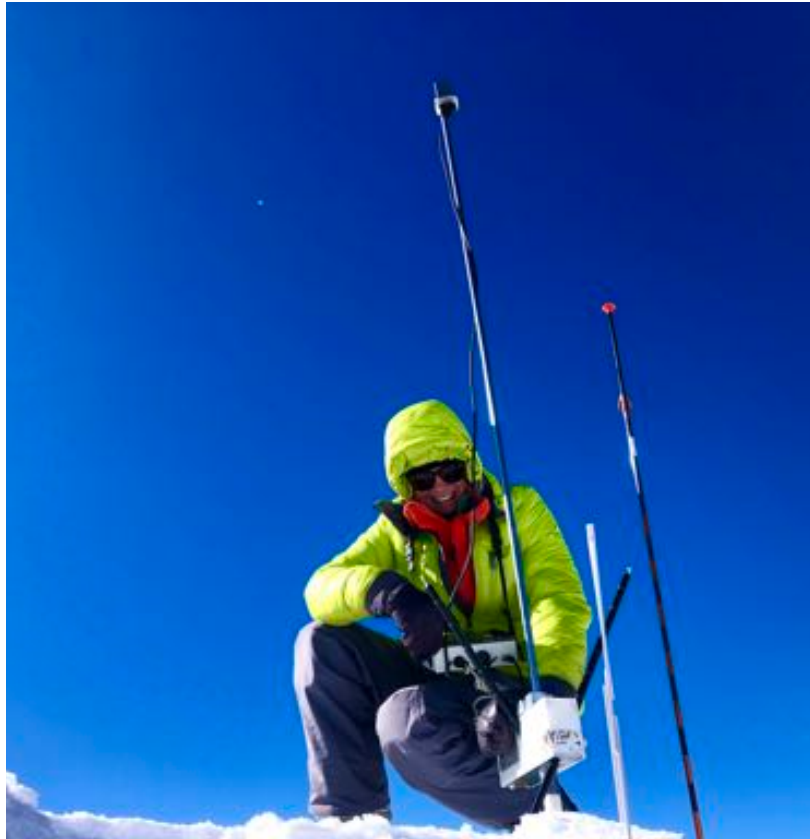


Celine Vargel collecting SSA with IRIS (Photo by Carrie Vuyovich)

# SMP



HP Marshall with the SMP (Photo by Megan Mason)



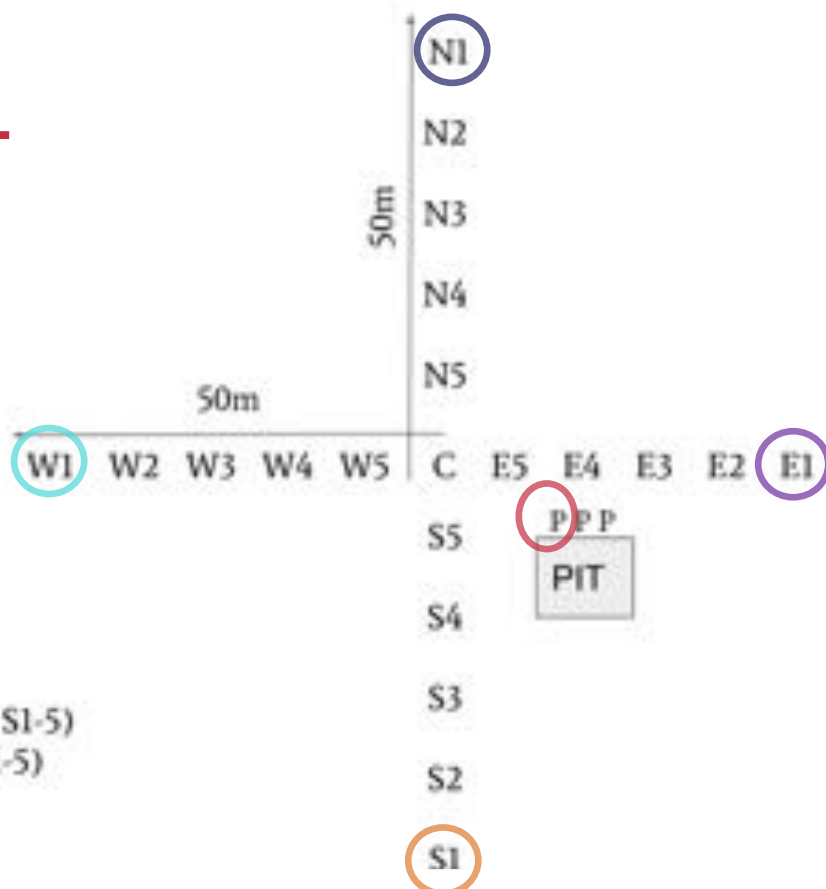
Megan Mason with the SMP (Photo by Kate Hale)



Ioanna Merkouriadi and Chris Hiemstra with the SMP (Photo by Juha Lemmetyinen)



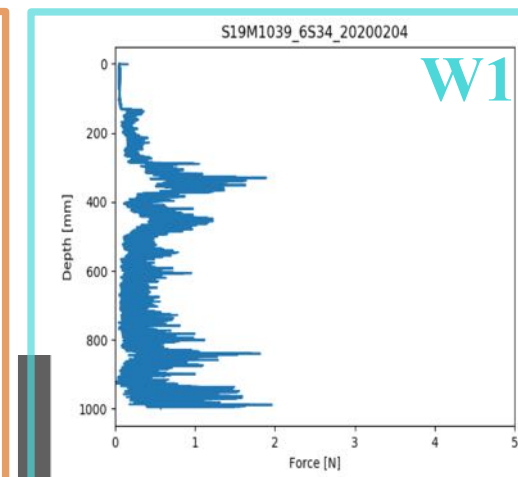
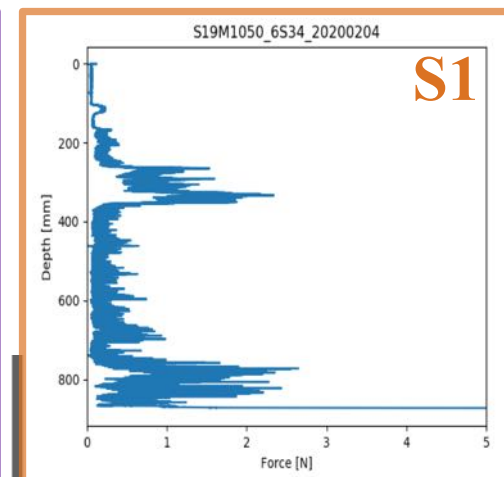
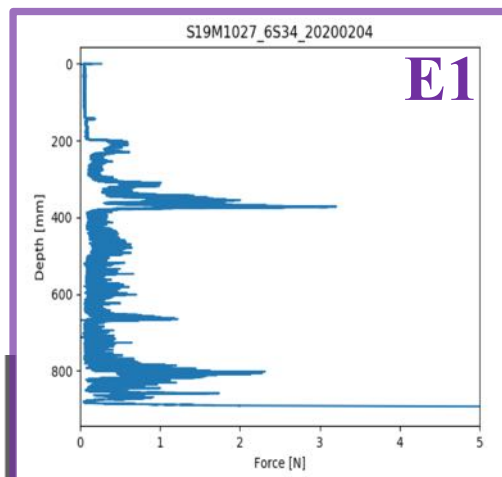
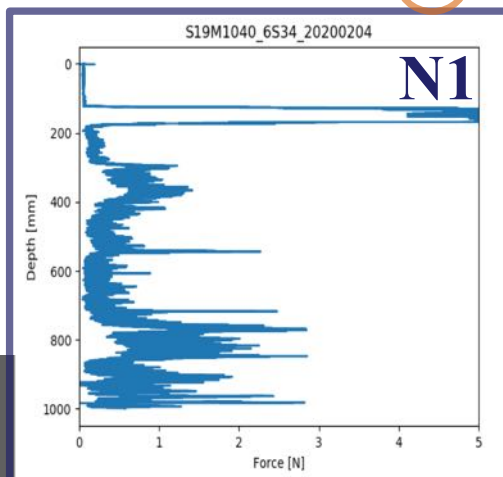
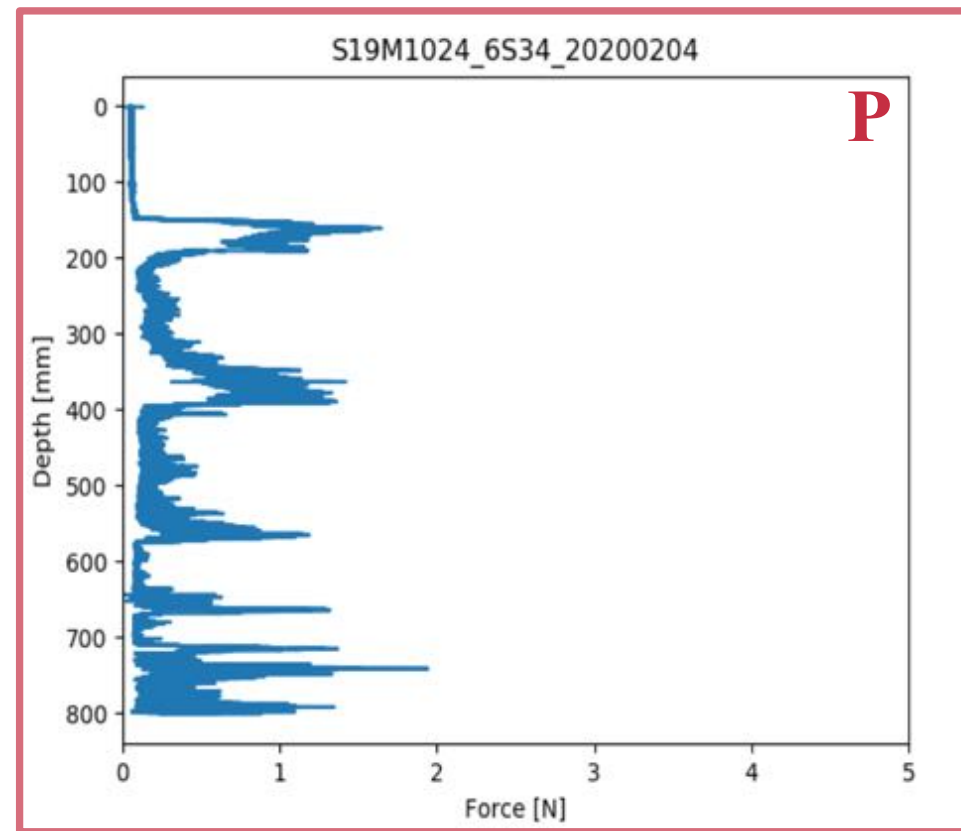
PIT: 6S34



Snow Pit:  
3 profiles (P)

Transect:  
North-South (N1-5, S1-5)  
West-East (W1-5, E1-5)  
Center (C)

Total Profiles: 24



(Slide from  
Megan Mason)





# ASD



Megan Mason with the ASD during the first Quantum flight (Photo by HP Marshall)



# Radar



HP's FMCW radar and Tate Meehan with GPR (Photo by HP Marshall)



Ryan Webb with GPR (Photo by Carrie Vuyovich)



# TLS

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Manny Salgado and the CRREL TLS set up (Photos by Art Gelvin)



# Passive Microwave Radiometer

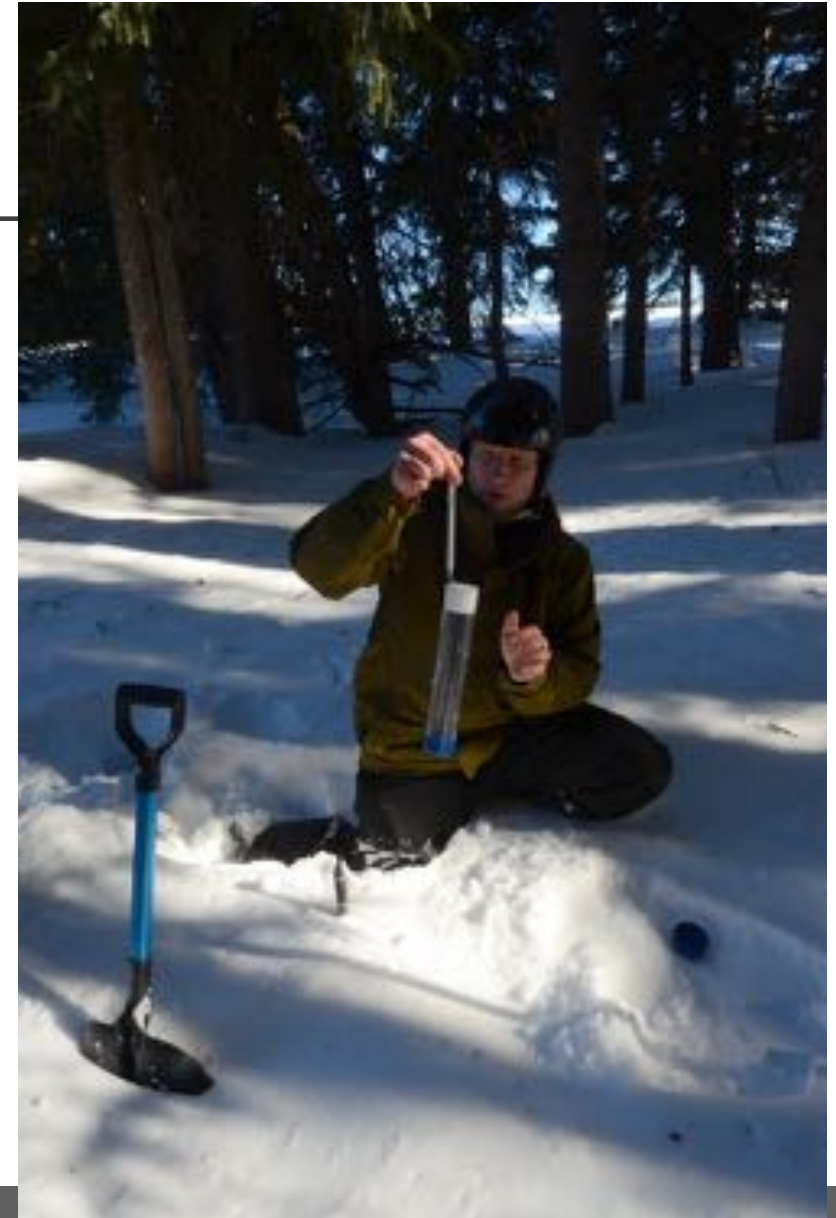


Mike Durand collecting data with his 18 and 37 GHz radiometers  
(Photo by Rick Sexton)

# Storm boards and snow stakes



HP Marshall and Carrie Vuyovich collecting SWE and LWC measurements at the snow stakes (Photos by Kelly Elder)



# Grand Mesa Airborne Instruments

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## **NASA Airborne observations:**

- L-band InSAR, UAVSAR (JPL) on JSC GIII
- Active/Passive microwave, SWESARR (GSFC) on NPS/CIRPAS Twin Otter
  - X-, dual Ku-band radar
  - X, K-, Ka-band radiometer
- Thermal IR (U. of Washington) on NPS/CIRPAS Twin Otter
- Reigl 1560i Lidar and CASI hyperspectral (Quantum Spatial) on Dynamic Aviation A90

## **Partner Airborne observations:**

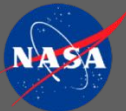
- FMCW Radar led by University of Alabama TOI Twin Otter
- Gamma Airborne Survey led by NOAA NOHRSC on Twin Commander





# Grand Mesa Airborne Schedule

Sunday, Jan 26	Monday, Jan 27	Tuesday, Jan 28	Wed, Jan 29	Thursday, Jan 30	Friday, Jan 31	Saturday, Feb 1
<ul style="list-style-type: none"> <li>- Unpack shipment</li> <li>- Assemble pit kits</li> <li>- New participants arrivals at CO</li> <li>- Transfer to Grand Mesa Lodge</li> <li>- Met station visit</li> </ul>	<ul style="list-style-type: none"> <li>- Briefing</li> <li>- Snowmobile Training</li> <li>- Pit/depth protocol review</li> <li>- Instrument prep and cross-comparison</li> </ul>	<b>UofAL FMCW Radar (flexible)</b>  SUS-V (integration)	<b>UofAL FMCW Radar (flexible)</b>  SUS-V <b>IKHANA door deliver to NPS</b>  Sentinel-1	<b>UofAL FMCW Radar (flexible)</b>  SUS-V <b>Door integration and approval</b>  Ecotress (2:57pm)	<b>UAVSAR</b>  <b>UofAL FMCW Radar (flexible)</b>  SUS-V  Landsat 8 (10:45am)	<b>Quantum Spatial Lidar &amp; Hyperspectral</b>
Sunday, Feb 2	Monday, Feb 3	Tuesday, Feb 4	Wed, Feb 5	Thursday, Feb 6	Friday, Feb 7	Saturday, Feb 8
DOWN DAY  <ul style="list-style-type: none"> <li>- 2nd shift participants arrive</li> <li>- Snow stake survey</li> </ul> <b>Quantum Spatial Lidar &amp; hyperspectral</b> <b>UofAL FMCW Radar</b>	<ul style="list-style-type: none"> <li>- New participants snowmobile training</li> <li>- SSA cross-comparison</li> <li>- Install Radiometer/thermocouple string</li> </ul> Ecotress (1:29pm)			<b>SWESARR/IR test flight (CA)</b>  <b>Transport to CO</b>	DOWN DAY <ul style="list-style-type: none"> <li>- 1st shift participants depart</li> <li>- Transfer to Grand Junction</li> <li>- Montrose to visit SWESARR/IR team</li> <li>- Clear radar targets</li> </ul> Ecotress (11:55am)	Snow stake survey <b>SWESARR/Thermal IR</b> <b>NOHRSC Gamma</b> <b>SWESARR/Thermal IR</b> <b>NOHRSC Gamma</b>  Sentinel-1 ASTER (11:07am)
Sunday, Feb 9	Monday, Feb 10	Tuesday, Feb 11	Wed, Feb 12	Thursday, Feb 13	Friday, Feb 14	Saturday, Feb 15
Media arrive       Sentinel-1	Media day (SWESARR)	Media day (field)  <b>SWESARR/Thermal IR</b> Ecotress (10:21am) Ecotress (16:52am)	Media day (field)  <b>UAVSAR</b>  <b>SWESARR/Thermal IR</b>	Media day (field)  <b>Quantum Spatial Lidar &amp; hyperspectral</b>	<ul style="list-style-type: none"> <li>- Check out field participants</li> <li>- Pack pit kits, and everything else</li> <li>- Package field material for shipping</li> </ul>	



**UAVSAR – AGL: 41,000 ft; Flight time: 30 min (3-4 flight days)**

**SWESARR/Thermal IR – AGL: 4,920 ft; Flight time: 3 hours (4-5 flight days)**

**Quantum Spatial – AGL: 5180 ft; Flight time: 5 hours (one flight day)**

**UofAL FMCW Radar – AGL: 1640-3840 ft; Flight time: 3 hours (up to 10 flight days)**

**NOHRSC Gamma – AGL: 500 ft; Flight time: 2 hours (two flight days)**

# Airborne Campaign

University of Alabama  
FMCW Radar



Quantum Lidar &  
Hyperspectral



UAVSAR?

NOHRSC Gamma



SWESARR/Thermal IR

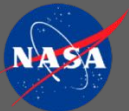
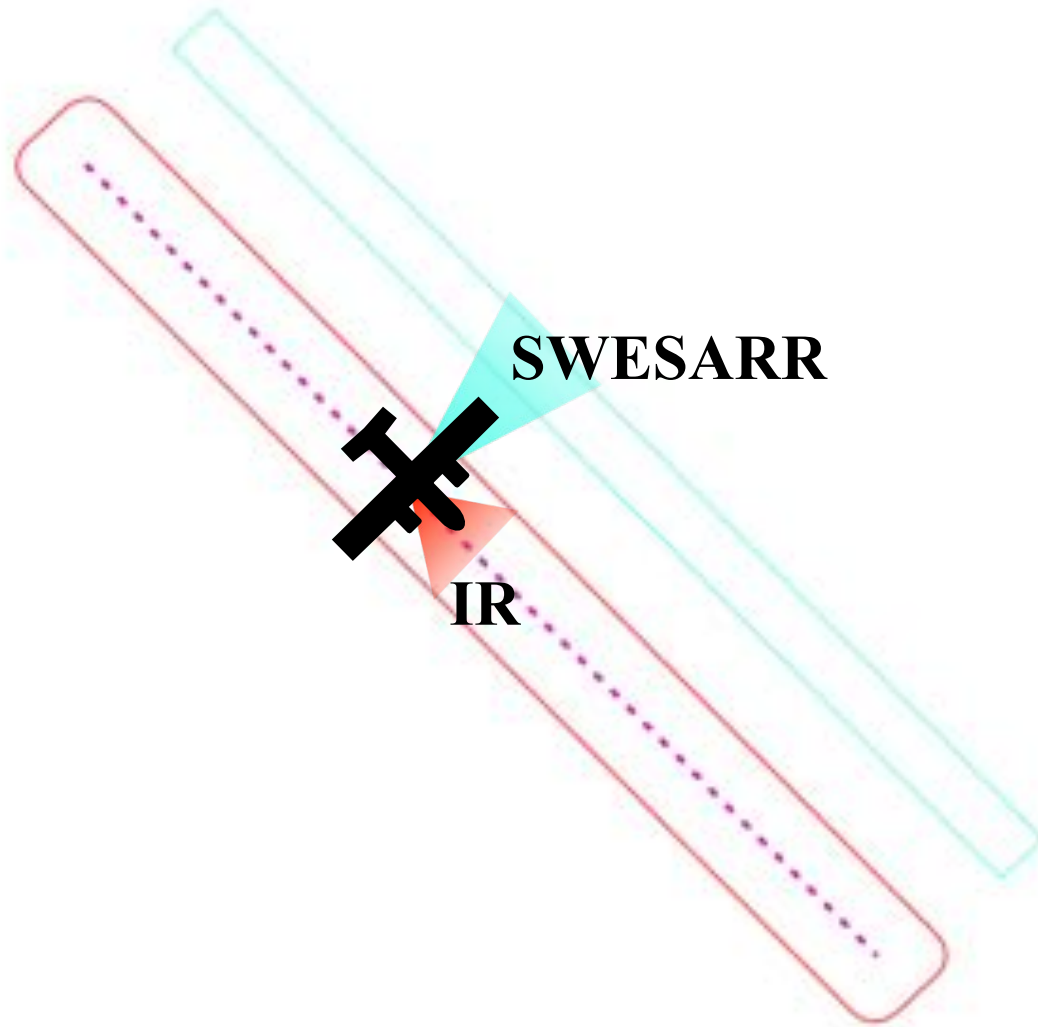


Photo by Kehan Yang



## Airborne Thermal IR

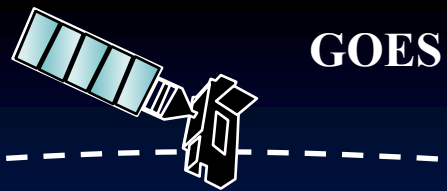


## Naval Postgraduate School Twin Otter



Thanks to Chris Chickadel @ UW APL!

SWESARR/Thermal IR team meeting with NOAA pilots



GOES



MODIS /  
ASTER



Airborne IR



Ground Observations

# Thermal IR Observations

**How should we interpret these GOES satellite observations and what they tell us about the snow-surface temperature?**

Comparison of GOES observations against other information at Grand Mesa with SnowEx 2020:

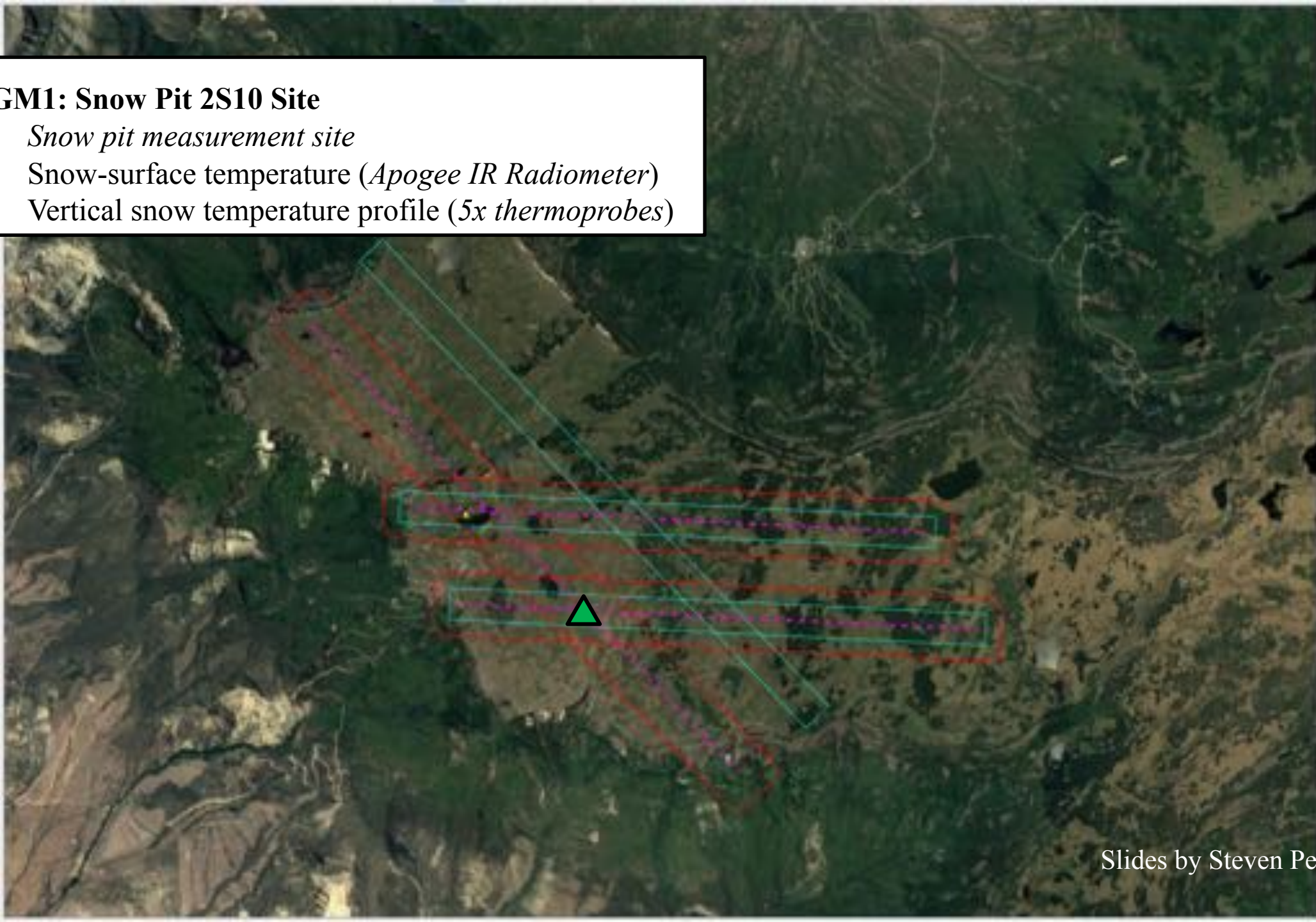
- Coincident IR observations at a range of spatial resolutions
  - GOES: 2000+ m
  - MODIS: 1000 m
  - ASTER: 90 m (or ECOSTRESS 70 m)
  - Airborne: ~5 m
- Time series of snow-surface temp. point measurements
- Time series of vertical snow temp. profile measurements

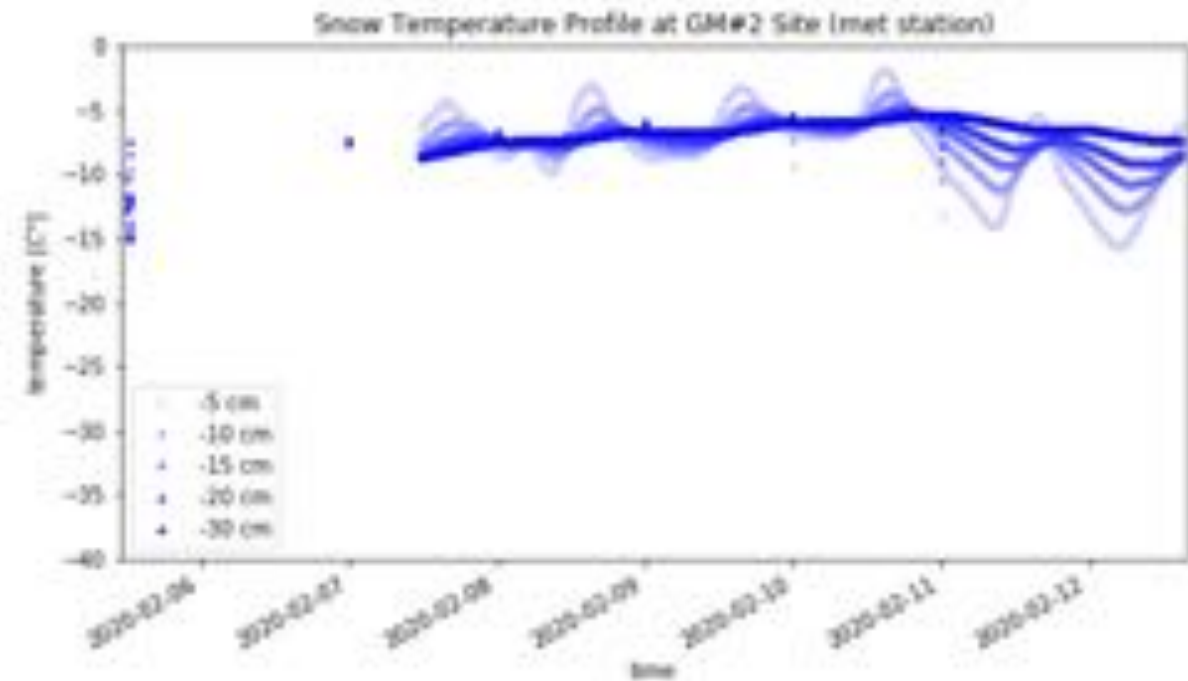
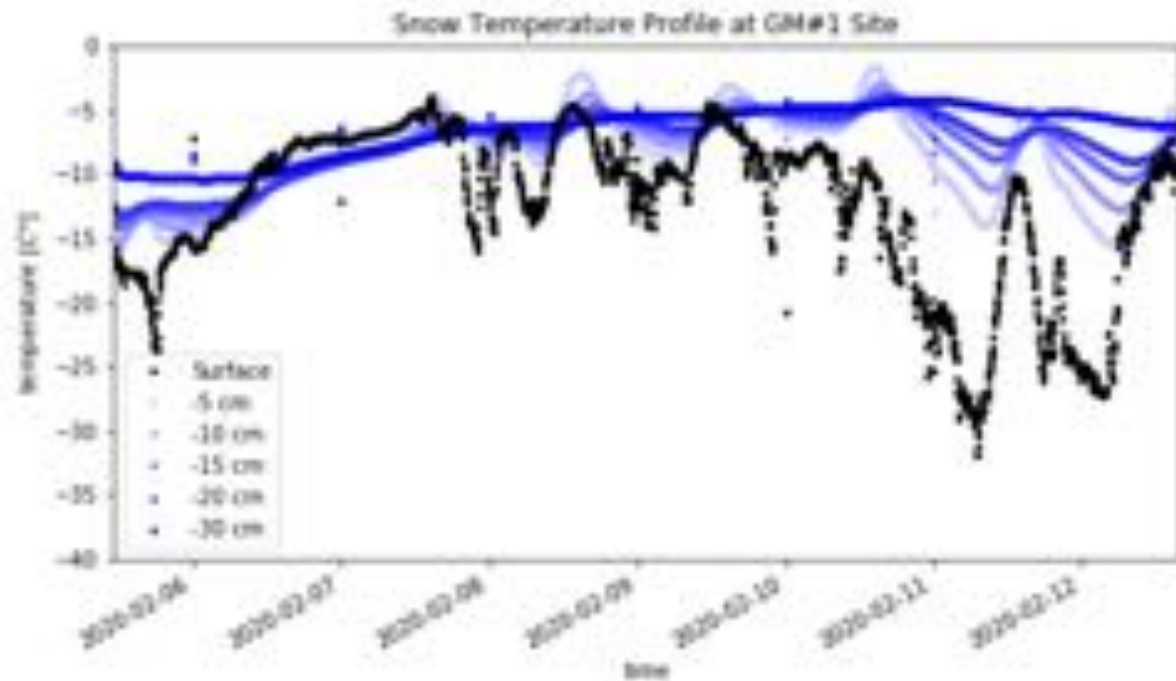




### GM1: Snow Pit 2S10 Site

- *Snow pit measurement site*
- Snow-surface temperature (*Apogee IR Radiometer*)
- Vertical snow temperature profile (*5x thermoprobes*)

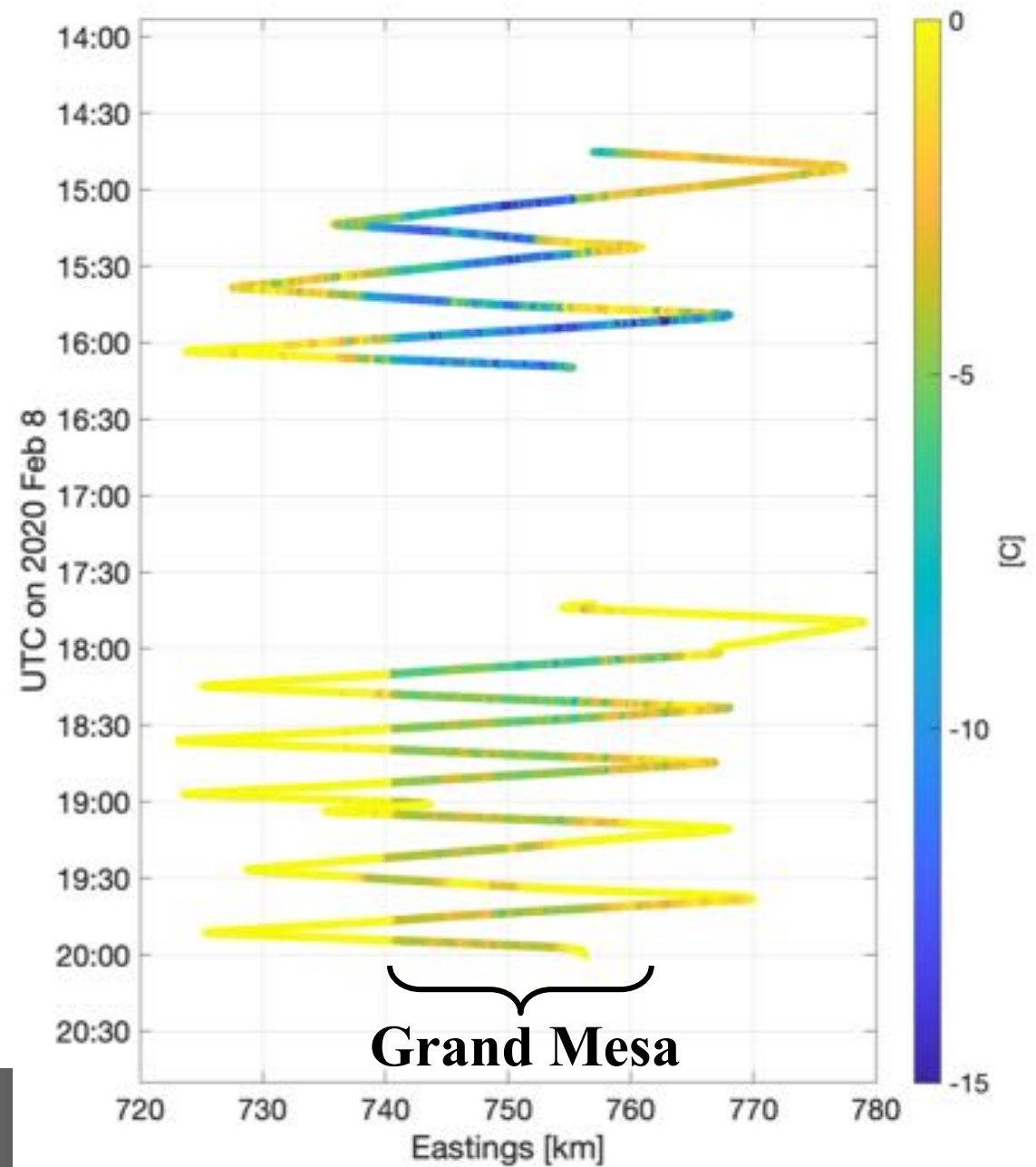




Preliminary snow-surface and depth profile temperature data  
<https://github.com/spestana/snowex2020-snow-temp>



# (Preliminary) Airborne IR Data (From Chris Chickadel)



**ASTER**  
**2-8-2020**

TIR band





# Preliminary SWESARR data

- 9 flights total
- 6 flights over Grand Mesa
- Total data is about 3.5 TB.
- Issues in precise time-server and GPS/IMU on the positioner. Both were circumvented by using secondary/backup systems.



(From Batu Osmanoglu)

# SnowEx 2020



Thanks to everyone who participated  
and supported this effort!!



# SnowEx2020 Expected Datasets

	A	B	C	D	E	F	G	H	I	J
	Category	Dataset Name	Dataset Lead/NSIDC submitter	Other Contributors/Data Collection	Data Format	Data Levels Expected			Affiliation	Email
Ground-based	Snow Pits	Snow profiles & stratigraphy	Carrie Vuyovich	HP Marshall, Kelly Elder, Chris Hemmstra, Multiple					NASA GSFC	carrie.m.vuyovich@nasa.gov
	Snow Depth	Magnaprobe	Chris Hemmstra	Multiple					ORREL	Christopher.A.Hemmstra@erdc.dren.nl
	Snow Depth	Manual (RevoTablet/Code)	Chris Hemmstra	Multiple					Boise State University	hemmstrc@boisestate.edu
	SWE	SWE Tubes (November)	Ludo Brucker	Carrie Vuyovich, Jyue Zhu, Haoran Shen					USRA	ludo@brucker@nasa.gov
	Snow change	Snow stakes & storm boards	Kelly Elder	Chris Hemmstra, HP Marshall, Jerry Newlin, Carrie					USFS	eldernewj@gmail.com
		SA	Mike Durand	Juha Lemmetyinen, Orlina Vargel, Kahan Yang					Ohio State University	durand.8@osu.edu
	Manostructure	Snow Casting	Lauren Farnsworth	Zoe Courville					ORREL	Lauren.B.Farnsworth@usace.army.mil
		SMP	Megan Mason	Ismael Markouriad, HP Marshall	PNT, CSV, PFFlevel-0 (raw), level-1 (clean)				Boise State University	meganmason491@boisestate.edu
		RMOW radar	HP Marshall	Scott Storms					Boise State University	hemmstrc@boisestate.edu
	Radar	GPS	Ryan Webb	Ryan Webb					University of New Mexico	webb@unm.edu
		GPS	Tara Maechan	HP Marshall					Boise State University	tanamaechan@boisestate.edu
		GPS	Randall Bonnell	Randall Bonnell					Colorado State University	Randall.Bonnell@colostate.edu
	Spectrometer	ASD	Jessie Lund	Megan Mason					University of Utah	lund.jessie@gmail.com
		ORREL TL	Art Gehl	Manny Salgado					ORREL	Arthur.B.Gehl@erdc.dren.nl
	Lidar	BSU TL	Jake Graham	Josh Embertine, Ahmad Hagarimulikhah					Boise State University	jakegraham@boisestate.edu
	PM Radiometer	Perovskite Microwave	Mike Durand	Mike Durand					Ohio State University	durand.8@osu.edu
	IR Radiometer	IR & Temp Profile	Steven Pentana	Jessica Lundquist					University of Washington	spentana@uw.edu
	Soil Moisture	In situ soil moisture stations	Mike Cosh	Alex White					USDA	?
	Soil Moisture	manual measurements	Ludo Brucker							ludo@brucker@nasa.gov
	Soil Moisture/SWE	COMOS	Mike Lewis	Amy Fischer					ERDC GRL	?
	Precipitation	Flux-volumetric precip gauge	Ava Barnes	Jim Mahoney, Paul Houser					Duke University	?
	Met Stations	Met Stations	Paul Houser	Paul Houser					Georgia Mason University	phouser@gaia.edu
Airborne	GNSS	1-Solid GNSS	Folding Cox, Kevan Feltz	HP Marshall, IS DARS					NASA JPL	?
	SAR	Active/Passive Microwave	Batu Omeroglu	Rafael Rincon, Ludo Brucker					NASA GSFC	?
	Thermal IR	Thermal IR	Chris Chickadel	Steven Pentana, Jessica Lundquist					University of Washington	?
	Quantum Spatial	Lidar	HP Marshall, Chris Hemmstra	ASD team					NASA	?
	Quantum Spatial	Hyperspectral	McKenzie Skiles	ASD team					NASA	?
	NOIRS Gamma	Gamma Radiation	Carrie Offenberg						NASA	?
GIS	RMOW Radar	RMOW Radar	Prasad Gopferli, Drew Taylor	Charles O'Neill					University of Alabama	?
	GIS data package		Chris Hemmstra						ORREL	Christopher.A.Hemmstra@erdc.dren.nl

Megan Mason, MS student, Boise State University, MEGANMASON491@boisestate.edu



NASA Terrestrial Hydrology Program (THP)  
Updates to SnowEx Community, April 16, 2020





# **THP Snow Program**

## Future Planning and Activities

# SnowEx 2019 Workshop

## 17 – 19 Sept 2019, Baltimore, MD

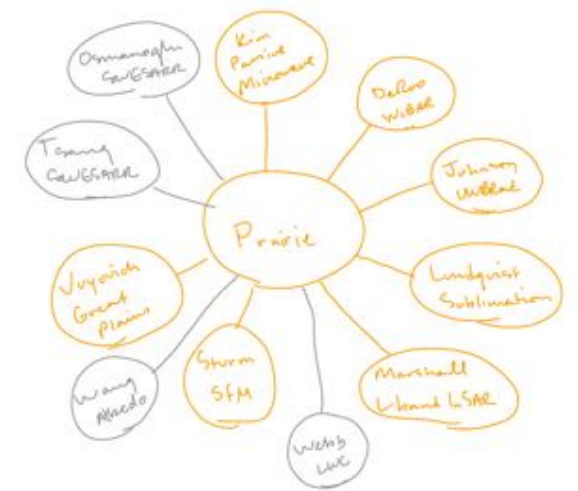
**Objective:** Meeting held to discuss SnowEx results and planning for future SnowEx activities, based on recommendations from the SnowEx Science Plan

### 21 “1-pagers” submitted:

Break-out groups on 2<sup>nd</sup> day to discuss 3 potential activities based on submissions

### Other outcomes and recommendations:

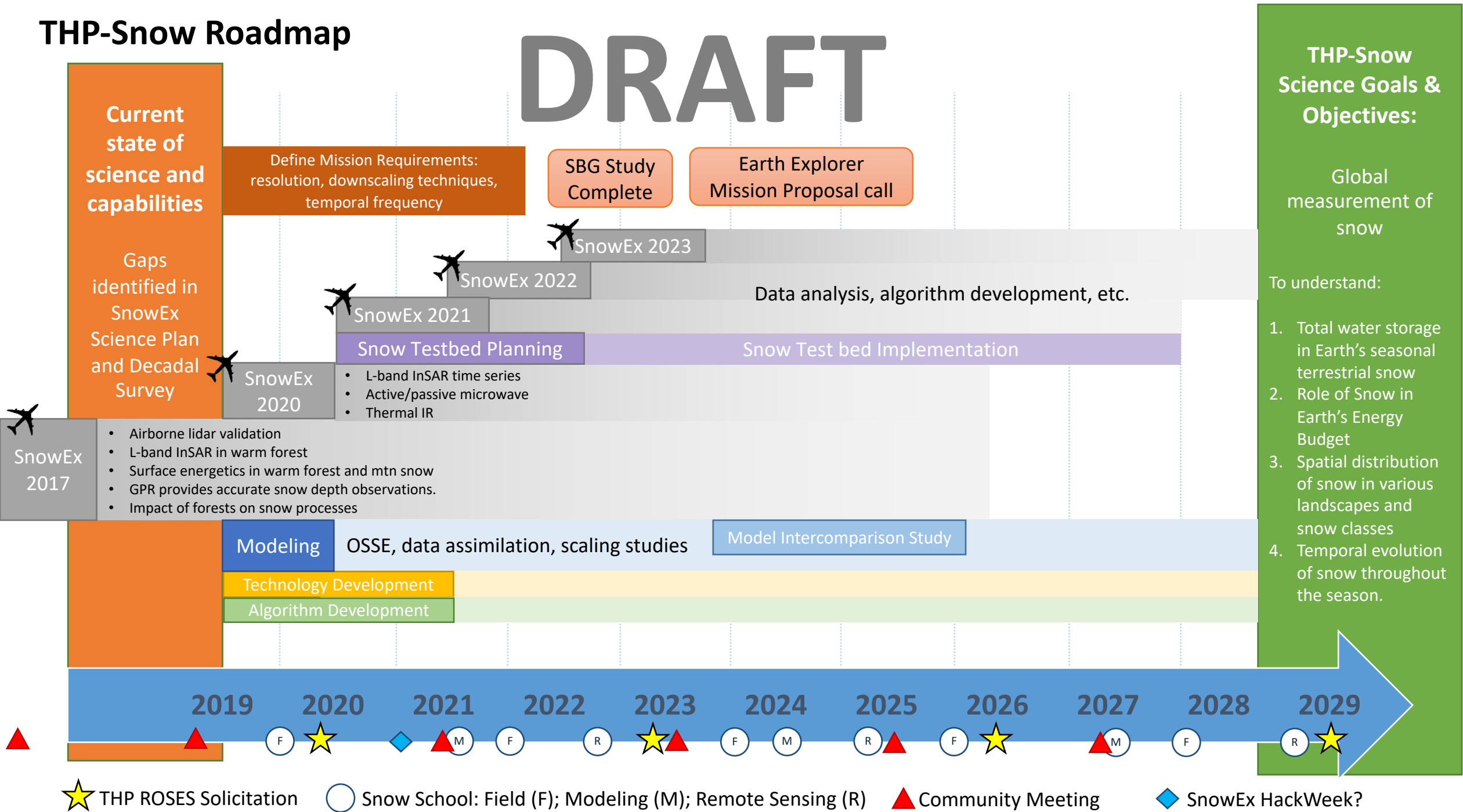
1. Albedo working group
2. Data availability after campaigns
3. Modeling/Observing System Simulation Experiment (OSSE) to support snow mission
4. Test bed sites



<https://snow.nasa.gov/workshops/snowex/2019>

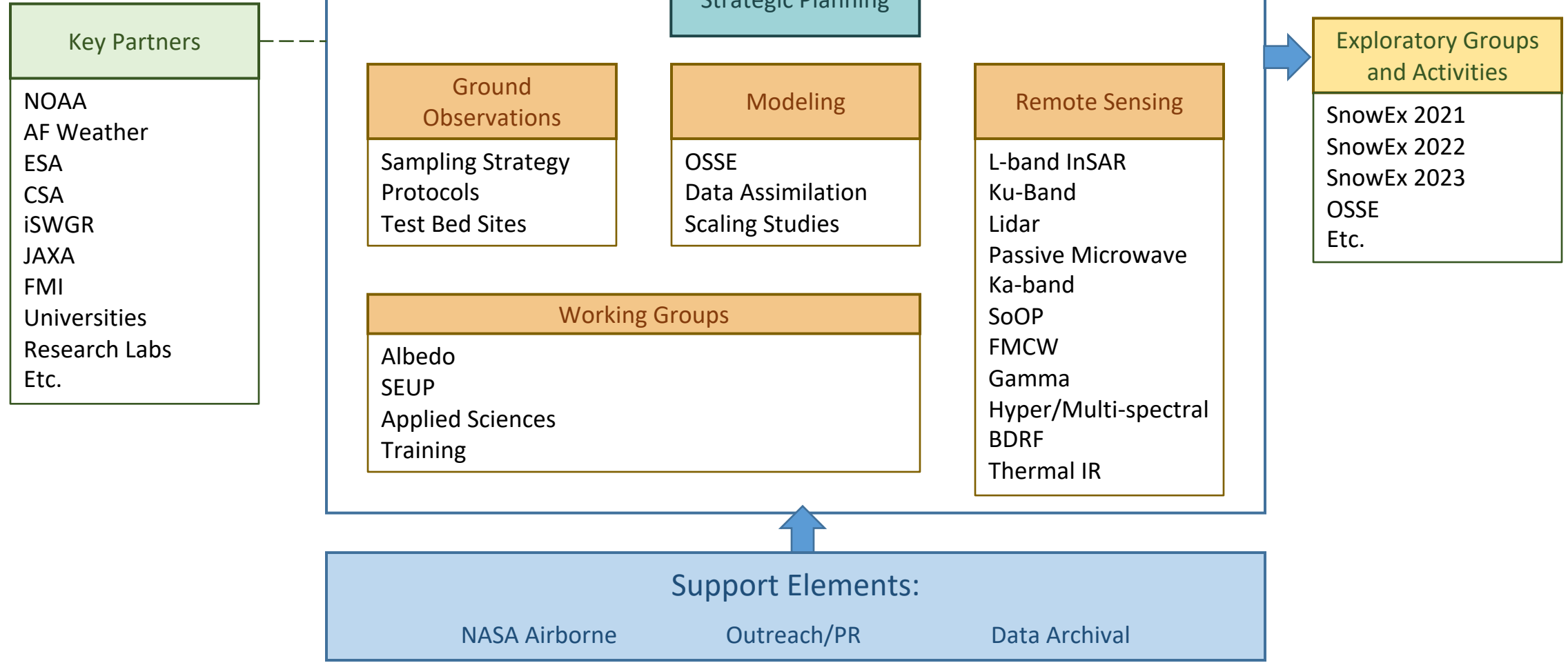
THP-Snow Roadmap

DRAFT





# THP-Snow Organization



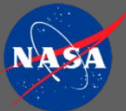
# THP-Snow Roles

**Strategic Planning group:** Help develop the roadmap, which includes helping to: refine the overall THP-Snow Goals and Objectives; develop a list of data, publications, algorithms, etc that need to be developed to reach our goals; identify the timing of key milestones and activities and planning snow efforts to meet those milestones; reach out to community members for input in various areas; develop and assist in the process for evaluating activities against the roadmap and science plan

**Snow Community roles:** Provide input to the roadmap in specific areas on what is the current science; what specific activities (i.e. observations, validation, etc) are needed or ongoing to push the community forward; help evaluate proposed activities in specific areas. POC for each area will help organize members and serve as contact for those looking to get involved

**Working Groups:** Investigate specific areas of interest to the snow community where additional effort is needed, e.g. to determine what observations are critical or evaluate value, conduct targeted analysis.

**Planning and Exploratory Groups:** Determine primary THP Snow and SnowEx objectives to be accomplished through specific activities, based on input from SnowEx Science Plan, Roadmap and 1-pagers. Define instruments, observations, site characteristics and strategy needed to meet the objectives. Develop rough cost estimate and schedule.



# THP Snow Program

## Next Steps:

- Develop a Roadmap for THP Snow with input across snow community
- Develop a process to evaluate submitted activities.

*In parallel, and based on outcome of Baltimore meeting:*

- Planning Groups to start evaluating field campaign options for 2020-2021
  - Albedo, Prairie
  - UAVSAR flights
  - Assess impact of COVID-19
- Exploratory Groups to start evaluating options for 2021-2022 and other efforts
  - Tundra/Boreal Forest
  - Modeling/OSSE work
  - Test bed/long-term sites





# Discussion/Questions?

Next Update Meeting: May 21, 2020 @ 1pm ET

